Duluth Ship Canal
North End of Minnesota Point at Canal Park
Duluth
St. Louis County
Minnesota

HAER No. MN-10

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

REDUCED COPIES OF MEASURED DRAWING

Historic American Engineering Record
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HISTORIC AMERICAN ENGINEERING RECORD
DULUTH SHIP CANAL

HAER No. MN-10

I. INTRODUCTION

Location:	Northernmost entry from Lake Superior to the Duluth-Superior Harbor, Duluth, Minnesota
Date of Construction:	1899-1902 (rehabilitated 1985-1987)
Present Owner:	U.S. Army Corps of Engineers Detroit District P.O. Box 1027 Detroit, Michigan 48231-1027
Present Use:	Channel from Lake Superior into the Duluth-Superior Harbor
Significance:	The Duluth Ship Canal still functions as was originally authorized, which was to provide a safe and navigable channel from Lake Superior into the Duluth-Superior Harbor. This channel provides a vital link for the commercial and industrial shipping of the region.
Related Project:	Duluth Aerial Lift Bridge HAER No. MN-44
Historian and Date:	U.S. Army Corps of Engineers, Detroit District, April 1990 C. Stephan Demeter, Commonwealth Cultural Resources Group, Inc., September 1993

II. HISTORY

The opening of Lake Superior to direct ship traffic with the lower Great Lakes was accomplished with the completion of the Saint Mary's River Ship Canal at Sault Ste. Marie in 1855. At this same time, town plats for the Upper and Lower Duluth communities were being drawn up on grounds (i.e., Minnesota Point) that had been ceded by the local Ojibwa/Chippewa only the previous year through the Treaty of LaPoint.[1] The growth of the Duluth-Superior region was, in fact, tied with this development and, over the next half century, it proved to be a major beneficiary.[2] The naturally sheltered bay formed by Minnesota Point at the mouth of the St. Louis River was earlier regarded as one of the finest harbors in the world. Unfortunately, in its natural state the depth of the channel into the harbor was only "from 8 ft to 9 ft, and the channel tortuous," ranging from between 100 ft to 500 ft wide. Although the situation improved somewhat after spring flooding, substantial efforts to improve access to the harbor were necessary.[3]

As early as 1857, the Minnesota Pointe Ship Canal Company had been organized by a number of Duluth businessmen with the objective of cutting a channel through Minnesota Point and providing more direct access to Superior Bay; however, support for the project quickly evaporated with the financial panic of that year.[4] In 1865, a breakwater was constructed at the foot of 5th Avenue East and Michigan Street in order to protect the city's outer harbor.[5] This facility was apparently rebuilt and improved five years later, in 1870, by the Lake Superior & Mississippi Railroad, which had recently completed its line between St. Paul and Duluth. This breakwater extended for 400 ft and was built at a cost of $50,000.[6] Shortly after completion, it was destroyed by a storm in 1871.[7] Between 1871 and 1872, it was rebuilt by the Corps and extended to 750 ft in length at a cost of $110,000.00.[8] Storm and ice damage to this structure over the next several years eventually led to its abandonment in 1878.[9]

The coming of the railroad added a new dynamic to the push for harbor development on the Duluth side of Superior Bay. In 1866, Lieutenant Colonel W. F. Reynolds of the Bureau of Topographical Engineers (i.e., U.S. Army Corps of Engineers) had, among other improvements, recommended the opening of a channel through Minnesota Point.[10] Federal activities mandated through the River and Harbor Act of March 2, 1867, were, however, limited to harbor and channel improvements associated with Superior, Wisconsin.[11]

In 1868, the Corps began several years of pier construction on the Superior side of the harbor. Breakwater construction and repair commenced on the Duluth side in 1871, with dredging operations beginning three years later.[12] Between 1868 and 1896, the Corps conducted approximately 44 projects at a total cost of $1,547,195.00, aimed at maintaining a usable channel into the harbor and providing docking services to the ship traffic in the harbor. Research indicates that this effort represented 1/3 of all the development projects undertaken during that time period.[13]

The federal harbor improvement project carried out at Duluth was initiated under the River and Harbor Act of March 3, 1871.[14] The enactment of this legislation ran concurrently with the construction of the Duluth Ship Canal. Completed in May 1871, this channel was developed as a joint venture by the City of Duluth and the Lake Superior & Mississippi Railroad at a cost of $43,791.84.[15] Work on the canal began during the fall of 1870. The implications of its impact on the commerce of Superior were alarming enough to move the governor of Wisconsin, the state legislature, and congressional leaders to request the War Department to take immediate action to stop the excavation. A court injunction was obtained on June 13, 1871, but proved too late to prevent the breach of Minnesota Point. Popular tradition has it that the citizens of Duluth heard of the court injunction prior to its arrival in Duluth. "Every citizen of Duluth was called out with shovels and picks to help dig on Sunday, April 30, 1871. Within three days water was flowing through Minnesota Point into Lake Superior."[16]

The court injunction was subsequently lifted but was soon followed by an order that Duluth build a dike from Minnesota Point to Rice's Point, thereby isolating the new Duluth Harbor from Superior Bay and the natural flow of the St. Louis River. Constructed at a cost of $76,404.38 between 1871 and 1872, the dike extended for a distance of 4,490 ft.[17] Due to the shallowness of the natural harbor, ice damage during the succeeding two seasons virtually destroyed this structure. By the spring of 1874, the dike was reported to be "...almost entirely gone from 3 to 10 ft below the surface."[18] Subsequent Corps observations made in 1879 noted that the dike was then "...entirely out of site and no longer serves the purpose for which it was constructed...although, as a drowned dam, it doubtless has some small effect upon the flow."[19] By 1881, the structure had ceased to be a topic of engineering consideration in harbor design. Having been destroyed as a result of the region's harsh environmental conditions, the remains of the leveled dike were simply removed as a component of the Corps on-going dredging operations within the harbor.

The construction of the Duluth Ship Canal had been designed to offer access to a protected inner harbor not directly exposed to the high seas of Lake Superior; however, as late as 1874, the Corps annual report noted that "the condition of the Harbor of DuLuth is such that it gives no anchorage for vessels, owing to its shallowness."[20] During the next several years, Corps dredging operations through the canal and along the railroad piers and the northeast margin of Rice's Point removed enough of the bottom to allow anchorage to vessels drawing 16 ft of water.[21] Although the legal squabbles between Duluth and Superior continued over this period, the River and Harbor Act of 1873 had extended Corps jurisdiction over the entirety of Superior Bay and "both entrances to the lake thereto." According to an 1877 United States Supreme Court decision, this extension of federal recognition made "...legitimate the entrance to Duluth Harbor."[22]

Although the canal did not actually pass to federal ownership until 1887, its operation and maintenance had become the responsibility of the Corps as early as 1873.[23] At

that time, the City of Duluth had placed timber cribs filled with stone on the bottom of the lake on either side of the canal. Completion of the piers was facilitated through outside aid, including $25,000 allocated by the federal government. A trestle ran the full length of the South Pier, providing access to the lighthouse during stormy weather.

The early structures were plagued by continual maintenance problems, caused by scouring and harsh weather.[24] In 1875, a large section of the North Pier titled toward the canal. To combat scouring, 200 cords of stone were placed on the canal side of the cribs, with an additional 310.2 cords added the following year. In 1879, 250 ft of crib had to be entirely renewed due to ice damage. In 1880, 325 ft of the North Pier and 190 ft of the South Pier were renewed entirely.

The North and South piers were improved by the respective addition of 865 ft and 305 ft of decking in 1882. In addition, 85 tons of riprap stone were put in the lake to protect the end of the South Pier. In this same year, the North Pier was again undermined by the deepening channel, and it inclined sharply toward the canal. It was drawn back and firmly secured to a double row of piles on the back by means of large iron rods, one end of which extended through and fastened to the face of the cribs.[25]

During the 1890s, the Corps increased its activities within the harbor. The impetus for this action was the onset of intensified iron ore mining in the nearby Mesabi and Vermillion iron ranges. During the 1880s, the major commodity shipped through Duluth Harbor was grain produced in western Minnesota and North Dakota, which was destined for Buffalo, New York.[26] In 1881, upwards of 62 percent of the trade originating out of Superior Harbor was associated with the newly developing lumber industry of northern Wisconsin.[27] By 1884, iron ore was being hauled out of the Vermillion range, and shortly thereafter the Mesabi range was opened to exploitation.[28] Ore was originally shipped out of Superior, but in 1892 the first

iron ore dock was built in Duluth. Two additional ore docks were constructed in Duluth before 1902.

In 1896, Congress combined the maintenance and construction operations of the two harbors under the Duluth-Superior Harbor Authority and authorized $3 million for harbor improvements and the enlargement of the ship canal. Congress also implemented the "continuous contract system," which replaced the previously piecemeal maintenance and construction operations with regularly scheduled improvements.[29]

The design and reconstruction of the Duluth Ship Canal was carried out under the direction of Major Clinton B. Sears of the U.S. Army Corps of Engineers by John H. Darling and Clarence Coleman. The new piers bracketing the canal consisted of parallel structures comprised of a stone filled timber crib substructure with a concrete superstructure. The South Pier was built between 1899 and 1901 on the south side of the existing South Pier. The North Pier was constructed between 1899 and 1902 on the south side of the existing North Pier. Some remnants of the old North Pier and the south protection pier may remain.

Channel and harbor improvements conducted by the Corps at Duluth-Superior between 1897 and 1902 entailed the removal of 21,697,243 cubic yards of dredge spoil. These activities opened up 17 mi of channel, ranging from 120 ft to 600 ft in width, and provided an aggregate harbor basin area of 360 acres running in excess of 20 ft in depth. By 1906, goods passing through Duluth-Superior Harbor amounted to 29,171,221 tons valued at $251,899,844. This accounted for fully 56 percent of the total tonnage that passed through the locks at Sault Ste. Marie and ranked the twin harbors third in the nation, immediately below New York and Philadelphia, for tonnage handling.[30] The intensity of this trade is even far more apparent when taken into consideration with the fact that it was seasonally restricted to a nine-month period between April and December.

Corps activities at Duluth-Superior had entailed the expenditure of $5,021,597.92 between 1867 and 1906. Goods transported through the port facility during this same period had an estimated value of $2,593,135,606. This was arguably a good investment on the part of the federal government, with expenditures amounting to less than 0.2 percent of the value of the total trade passing through the port.[31]

The growth of commerce can be readily expressed through tonnage rates for goods entering and leaving the harbor. As of 1873, when the Corps took over the operation of the Duluth Ship Canal, the water-borne trade amounted to 281,602 tons.[32] In 1880, an estimated 302,805 tons of goods were shipped through Duluth Harbor. The majority of the trade passing through Duluth at that time reportedly consisted of goods enroute between the provinces of Quebec and Ontario and the province of Manitoba.[33] By 1896, when the two projects at Duluth and Superior were combined under one budget, the shipment of goods through the twin harbors amounted to 7,886,833 tons. Between 1900 and 1910, the annual tonnage rate averaged approximately 23 million tons; this increased during the succeeding decade to an average of about 48 million tons. The following decade saw a low of 30,083,555 tons during the post-war recession of 1921 and a high of 60,385,767 tons in 1929. In 1932, during the Great Depression, tonnage slipped to 10,519,804 tons (the lowest rate since 1898). The tonnage between 1933 and 1940 averaged about 36.8 million tons annually. This figure increased to an average of 70 million tons during the 5-year period of the Second World War. Trade statistics for the remainder of the decade, up through 1950, indicate a minimal decline averaging approximately 64 million tons annually.[34]

Data relating to the variety of goods and commodities entering and leaving the Duluth-Superior port facility indicate that the vast majority of this commerce consisted of bulk, unpacked, freight. In 1921/22 it was estimated that this element accounted for upwards of 97 percent of the total trade. At that time, coal and oil accounted for 91.8 percent of the port's

total receipts. Shipments out of the port were dominated by iron ore (84.3 percent) and grains (15.3 percent).[35]

In 1901, Captain D. D. Gaillard (1935) began a series of wave measurements at the Duluth Ship Canal, which were a significant part of his study on the impact forces of shallow-water waves.[36] During the period between 1901 and 1903, Gaillard secured over 2,000 observations at five different localities around Lake Superior. Most of them, however, were taken near the outer ends of the ship canal piers. This location was of particular importance as the surface profiles of the waves could be obtained by means of photographs taken while the wave was traveling parallel to the vertical face of the South Pier. Gaillard's work resulted in the report *Wave Action in Relation to Engineering Structures*, first published in 1904 and reprinted in 1935. To this day, the study remains a classic work in the field of coastal engineering. Captain Gaillard went on to a distinguished military career, which included work on the design and construction of the Panama Canal.[37]

III. THE SHIP CANAL

A. Project Setting

The Duluth Ship Canal is a man-made structure that provides an entryway from Lake Superior to Duluth Harbor. It is situated across the north end of Minnesota Point, a natural sand breakwater that is approximately 8 mi long. The Point separates Lake Superior from a narrow bay, which is known as Allouez Bay, at the southeast end and Superior Bay for the remainder. The northwest portion of Superior Bay is designated as Duluth Harbor. The Corps of Engineers owns the property immediately adjacent to both sides of the canal, which is bounded by commercial development on the north side and residential development on the south side. The Duluth Aerial Lift Bridge, which is listed on the National Register of Historic Places, spans the canal.

The U.S. Government complex at the Duluth Ship Canal consists of a channel and piers, two lighthouses, one range light, the Corps of Engineers Duluth Area Office, the Marine Museum and Visitor Center and grounds, and three park areas. The two parallel piers, each 1,720 ft long, are 300 ft apart for approximately 1,250 ft from the Lake Superior entrance, at which point the channel width increases to 540 ft to the Duluth Harbor Basin. The lighthouses are located on each pierhead at the Lake Superior end of each structure. The rear range light is located on the South Pier, on the lake side of the aerial lift bridge, near the point at which the canal begins to widen. The U.S. Army Corps of Engineers Duluth Area Office, and Marine Museum and Visitor Center are located adjacent to the North Pier.

B. Area Office, Marine Museum and Visitor Center

The Duluth Area Office is located adjacent to the east abutment of the aerial lift bridge on the north side of the canal. The property was purchased in 1903 and the Area Office was completed in 1906. Also constructed at this time was the vessel yard located on Superior Bay south of the ship canal. This yard serves as a primary base for Corps vessels on Lake Superior and has a machine shop, welding shop, and twin warehouses, including a carpenter shop, a garage, and a two-story residence.[38]

The Duluth Area Office has undergone considerable change throughout its history. In the early 1940s, the original office building was expanded to almost twice the size of the 1905 structure. The addition involved the eastern two bays, which can only be detected, on the exterior, through careful observation. The gray exterior trim paint, which was used after completion of the addition, was removed in 1978, after required tuckpointing was completed. In 1984, thermal efficient windows were installed.[39] The cornice and eagle on the Area Office structure were repaired in 1989.

The government property adjacent to the piers was enclosed by concrete walls prior to 1909. The tracts were filled to grade, requiring the deposit of about 50,000 cubic yards of material.[40] The property south of the canal, as well as that located on the north side of the canal and west of the bridge, has been maintained as a park.

In 1973, a Marine Museum and Visitor Center was constructed adjacent to the Area Office. This structure was not designed to be compatible with the existing turn of the century architecture of the Ship Canal and Area Office. In 1979, the Museum was expanded and connected to the Area Office. The museum grounds are used for display purposes and storage. The museum preserves the last of the original iron lamp-post bases from the ship canal, as well as the terra cotta tile wall gauges.

C. Description of Property

The pier foundation cribs descend 22 ft below the harbor datum with concrete structures that rise 10 ft to 18 ft above that plane. The substructures are stone filled timber cribs. Riprap has been placed in the canal and Lake Superior, adjacent to both piers. The superstructures are comprised of 167 concrete monolithic blocks, which were held in place by concrete footing blocks resting on the timber cribs. Rehabilitation between 1985 and 1987 resulted in the addition of stonefill and steel sheet piling along both sides of the piers.

Galleries, with a 3 ft ceiling, were constructed through the length of the piers. Access to the pierhead was by means of a cart on tracks, which an individual could propel from a reclining position. The galleries in the pierhead were constructed with 10 ft ceilings. The purpose of the galleries was to provide access to the pierheads during rough weather; however, they were useless for this purpose as they would fill with water during rough weather. Although the galleries had been filled with concrete in the 1950s, during the 1985-87 pier rehabilitation,

cracks were repaired in the roof of the South Pier gallery. The north gallery roof did not require repair.

The general form of each pier consists of a walkway and a pierhead. The visible superstructure is composed of weathered concrete. The walkways are 12 ft 3 1/2 in wide between 3 ft high parapet walls. The original drainage features, which were small holes bored through the parapet wall, were supplanted by large 1 ft × 2 ft scuppers in several monoliths. Between the Visitor Center and the shoreline, a sidewalk, benches, three small monuments, and stairways down onto the pier are provided for visitors. Lighting for the piers is provided by 32 custom made, 15 ft galvanized steel poles with 8 ft davit arms. Four spot lights are located near the aerial lift bridge. Tile water level gauges and bronze plaques were original decorative elements on the structure. The water level gauges were located at the east and west ends of the South Pier. These were constructed of terra cotta tile and included foot markers for measuring water level at each end of the canal. The gage located at the south pierhead included a square polychrome mosaic of an eagle. Gauges were removed in 1985 and are now stored in the Marine Museum. Bronze plaques commemorating the construction of the piers were located alongside the steps to both pierheads and have been stored in the vessel yard since rehabilitation of the piers.

The original lighting, placed at the turn of the century, consisted of 12 ft ornamental poles and ball globes with 60 watt lamps. The original lamps were first powered by natural gas but were converted to electricity in 1904. Their design, however, was not compatible with the harsh weather of Lake Superior; many were broken off by waves and blocks of ice hurled by the waves. In the late 1940s, the Duluth District experimented with new lighting systems. The purpose was to "find a lighting system, marking the canal, that can be distinguished from numerous city lights in the background."[41] Insect repellent lights were first tried, due to the fact that they were the only colored lights available at the time. In 1947, amber colored bulbs were obtained and inserted in 32 of the 124 ornamental lights that lined the canal.

As a result, the ship canal stood out as a definite landmark to operators of incoming craft. The lights were also more effective in fog, as they had far more penetrating power than ordinary bulbs. After these experiments new lighting was planned. The new replacement units were Suburbanairs, manufactured by Line Material Industries. The 2,500 lumen, 189 watt lamps first used in the luminaries were amber colored. Sixty-four of the old units were replaced by 32 Suburbanaires. These lights, with their high intensity and little glare, made it easier for skippers to navigate into the canal and to determine their position in bad visibility conditions.[42]

The lighthouses are owned and maintained by the U.S. Coast Guard. The rear range light is listed on the National Register of Historic Places. It has a pyramidal steel skeletal frame supporting a round watchroom and an octagonal cast iron lantern. Built between 1900 and 1901, it is one of the oldest skeletal lighthouses on Lake Superior.[43] The lighthouses on the pierheads are not considered to be significant with respect to the "evolution of lighthouse design and construction methods in response to the changing requirements of Great Lakes shipping."[44]

Other improvements to the piers included the installation of a current-indicator light in the early 1950s. The lights relay, to approaching ships, electronically-received measurements of the velocity and direction of current in the entrance channels.[45] Presumably this was when the radio tower was installed on the South Pier. During the 1985-87 pier rehabilitation, the radio tower was removed.

D. Need for Rehabilitation

An evaluation of the North and South piers in 1982 estimated that the remaining life of the structures was from nine to eleven years.

Relatively speaking, the North and South piers have required a minimum of maintenance since construction. In 1956, the presence of longitudinal cracks in the center of

the piers was detected. It appeared that the entire crib and superstructure were in a failure mode. To counter this threat, horizontal tie bolts were placed through each monolith and the galleries were filled with concrete. Visible evidence of this existed in the presence of tie rod ends protruding out of the sides of the pier, just above water level, and of small circular patches in the walkway as well as the longitudinal patch in the center of the piers, which extended from the shore to the pierheads.

On May 23 and September 23, 1980, two ships, the *Lake Winnipeg* and *D. G. Kerr*, respectively, caused a total of $200,000 damage to the North Pier. The oak timber cribbing sustained extensive damage. Reconstruction of the damaged areas was undertaken by the Zenith Dredge Company and continued into June 1981.[46]

The alignment of the North and South piers was still very good. There was little evidence of monolith settlement, which gave the appearance that the substructure was in a stable condition. The joints between individual monoliths were tight and showed no signs of horizontal or vertical settlement; however, the bottom of the timber cribs were as much as 13 ft to 28 ft above the channel bottom. A stability analysis revealed that safety factors against sliding and overturning were below acceptable levels. Since the top of the slope of the channel meets the bottom of the cribs, and the channel bottom is below the tips of the supporting piles, a potentially hazardous condition existed. Additional scour on the channel side coupled with a severe storm could result in a failure and blockage of the channel to vessel traffic. The channel is expected to continue increasing in depth over time due to the scouring action of the passage of the largest ships on the Great Lakes.

Information from an underwater inspection of the substructure indicated that there was a loss of stone from the timber cribs on both the North and South Piers. A 1978 inspection report, prepared by the St. Paul District, indicated that several of the crib joints on both piers were separated by as much as 4 in, which would allow the crib stone to be washed out by the

wave action of Lake Superior and commercial vessels using the canal. With the loss of crib stone in the timber substructure, eventual settlement and failure of the piers could be expected to occur.

Wall surfaces of each monolith on both the North and South piers had many horizontal surface cracks. The cracks were larger and more severe near the top of the parapet walls. There was considerable joint deterioration along the entire North and South piers where the monoliths rested on the footing blocks. The footing blocks were stable but evidence of spalling due to weathering and wave action was present.

In 1975, an experiment with resurfacing two parapet walls on the North Pier was implemented. The resurfacing consisted of a 3/38 in thickness on one parapet and a 3/16 in thickness on the other of a fiber-reinforced, latex-modified material. Six years later, in 1981, the surface showed signs of minor cracking at the bottom of the parapet walls where water was able to enter the original concrete. Other types of measures and resurfacing have been tried over the years, including grout-injection of the cracks, grout mixtures and concrete patching.

Rebound hammer tests made along the superstructure showed a weakened condition in the concrete. This was verified by taking a number of cores along the piers. The cores revealed that the monoliths were composed of what appeared to be only a troweled-in surface coat of 1 in thickness or less with a loosely cemented interior. The interior core pieces were retrieved as rubble. The aggregate pieces were flat and appeared to originate from surrounding beach areas. The aggregate, for the most part, was arranged with the long flat sides in a horizontal position. This construction, plus the lack of cement, seems to be the reason for development of the many horizontal fractures in the superstructure.

The concrete parapets on the North and South piers were in an advanced stage of deterioration with all monoliths showing varying degrees of cracking and spalling. The cracking

of the parapets ranges from surface cracks to full depth horizontal cracking. Where the full depth horizontal cracking was occurring, there was horizontal movement of the parapet walls. On the North Pier, one entire northern parapet wall on one monolith was washed away during a severe storm in 1977.

There was also an extensive amount of leaching at the cracks. This was most noticeable at the lower one-third of the parapets, indicating that water chemically reacted with the concrete to produce deterioration on the inside of the parapets. Spalling of the parapet walls is not as severe as the cracking, but is the next step in the deterioration cycle of concrete after cracking occurs.

The walking surface of the North and South piers was in relatively good condition with minor cracking and spalling in various areas. On the North Pier, there was an electrical cable on the wall surface, which was protected by a piece of steel angle. This was an obstruction to the water drainage from the walking surface since it was blocking the existing drainage scuppers. On the South Pier, the electrical cable was buried in the concrete walking surface. The cables on both the North and South piers provided power to the pier lighting systems and the lighthouses.

The lighthouse on the South Pier has undergone significant change through time. The building is constructed of brick masonry. Through the years, two windows have been removed and the remaining ones bricked in. Entryways on the north and east facades have also been bricked in. The building has been painted white and the red shingles have been added to the roof. The clear glass in the light tower has been replaced with green. Finally, the original fog horn was removed and replaced with a different pitch horn; however, due to public pressure, a horn with the original low pitch was reinstalled.

E. Ownership and Future

The Duluth-Superior Harbor remains a vital link for the commercial and industrial business of the region, and the Duluth Ship Canal is the major entrance and exit for shipping vessels. During its early history, the Duluth-Superior Harbor was viewed "of the first importance" due to the iron ore, grain, coal, lumber, and other commodities which were forwarded and distributed through harbors.[47] Duluth now serves as a terminal for grain, iron ore, coal and lignite, limestone, and building cement. The Duluth Ship Canal still functions as originally authorized, which is to provide a safe and navigable channel from Lake Superior into the Duluth-Superior Harbor.

ENDNOTES

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9. War Department, 1879, p. 1466.

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11. War Department, 1927, p. 1245.

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27. War Department, 1881, p. 2026.

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29. Hall, 45-47; Merritt, 339; War Department, 1927, p. 1245.

30. War Department, 1907, pp. 588-89.

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33. War Department, 1881, p. 2023.

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37. Merritt, 339.

38. Hall, 46.

39. Courtland Mueller, Area Engineer, U.S. Army Corps of Engineers, Duluth Area Office, interview by author, 1985.

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